Seismic Data Processing

Our Services:

- Model building /Depth Imaging
- CRS
- SRME
- IME
- Field QC and in-house processing
- AVO/Inversion
- Reservoir Characterization
- Acquisition design
- Interpretation
- Tape transcription and recovery

DMT Petrologic GmbH is dedicated to providing competent geophysical services and innovative seismic data solutions to the oil and gas industry. Operating since 1998 from Hannover, Germany, effective cooperation with strategic partners leads to conduction of complex interdisciplinary projects from acquisition support over processing towards analysis and interpretation.

Our strength lies in our experienced team with over 20 years of experience directly in seismic data processing. This involves 2D and 3D processing, both land and marine, in time and depth, utilizing various software packages. Processed areas include projects in Eastern and Western Europe, North Sea, Russia, Kazakstan, Caspian Sea, Middle-East, North and West Africa, India, Bangladesh, Middle and South America.

With the introduction of a supplementary 64-bit Linux cluster in November 2007 we increased performance on large-scale 3D and imaging projects.

Our main processing platform is ProMAX which has been significantly enhanced through the addition of 3D CRS (Common Reflection Surface Stack) technology and ProManager fully utilizing the capabilities of our distributed processing environment. ProMAX is complemented by more specialised software packages such as Tsunami Imaging and GOCAD to cater for specific geological objectives.

The addition of 3D Prestack Depth & Time Migration Software from Tsunami led to a reduction of computation time (cost!) with enhanced flexibility and improved imaging quality. Earth Decision Sciences GOCAD velocity and reservoir properties suite allow accurate layered and structural depth models combining seismic and well information in an intelligent way.

Our entry into the DELPHI consortium in 2007 has allowed us to implement their state-ofthe-art surface related demultiple code - SRME - as well as their internal multiple elimination method - IME.

Moreover, we have broadened our range of services: The KINGDOM software suite provides us with interpretational capabilities and the latest version of Hampson-Russell gives us enhanced Reservoir Characterization techniques. For the development of reservoirs, both acoustic impedance and simultaneous AVO inversion are the key to derive reservoir properties from seismic such as porosity and fluid fill.

In addition to our cooperation in Cairo, a fully equipped processing centre with local and international staff was opened in Tripoli in 2007.

In a self-critical pursuit of constant improvement, we have implemented an ISO 9001 - 2000 certified Quality Management System.

DMT Petrologic GmbH

Karl-Wiechert-Allee 76
30625 Hannover, Germany

Phone +49-511-5413917
Fax +49-511-5414313
info-petrologic@dmt.de
www.petrologic.dmt.de

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Depth Imaging

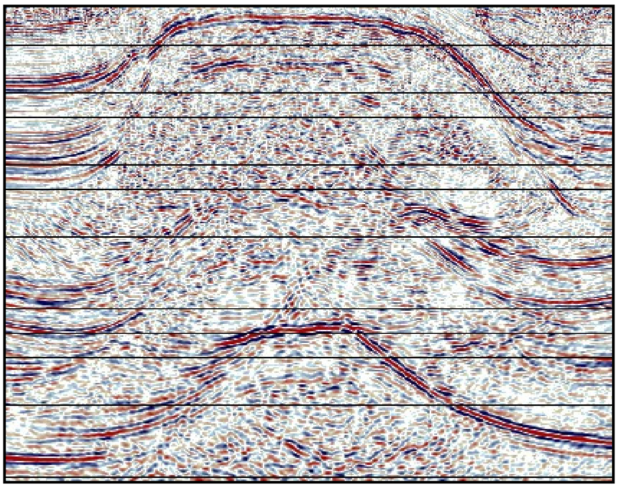
Strong lateral velocity variations associated with complex geological structures require imaging in depth. The benefits are

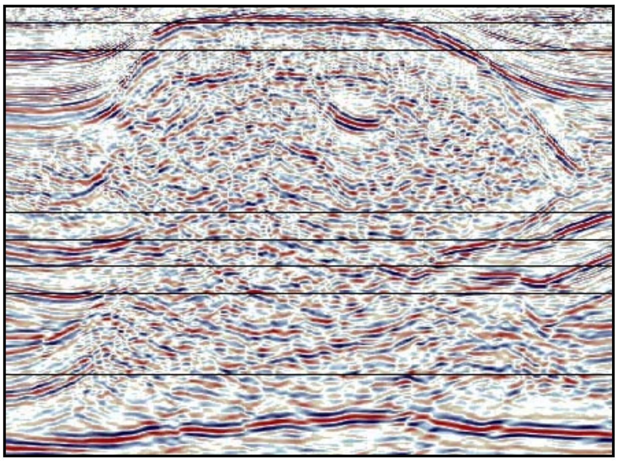
- Correct lateral positioning
- Correct vertical positioning- no pull-up or sags
- non-hyperbolic events caused by ray-bending at layer boundaries can be
- stacked and imaged properly
- An accurate velocity model can be derived through the iterative improvement of depth (CRP) gathers

Several marine projects have been performed, where effects caused by the presence of overlying gas complicating the target structures also had to be taken into account. Many 2D land projects, often involving salt tectonics have been undertaken. Here optimized velocity model analysis at the start of the project using wells and seismic (depth, gradient and time) ensures an accurate and timely result. The time migration on the right is unclear on the flanks of the salt-dome and shows considerable pull-up under the salt.

The corresponding depth section after accurate velocity model determination and prestack depth migration we see a considerably improved section. If wells are not available, Geological velocities can be determined directly using a Kirchhoff shot migration method that calculates diffraction patterns for a range of velocities and resort the data to CVS panels. Alternatively a model can be prepared from stacking velocities using the inverse Dix method.

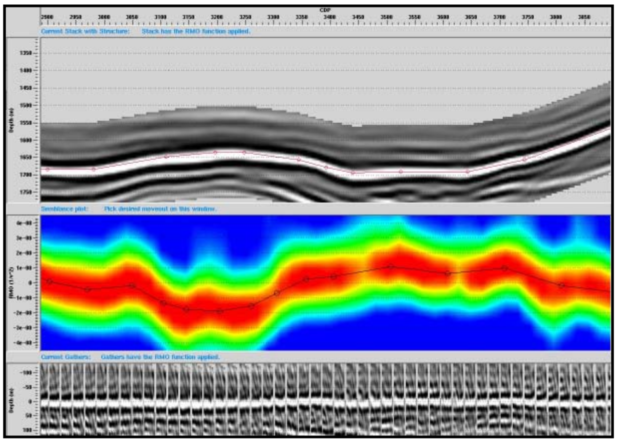
Issues such as large computational times and costs are no longer so critical due to the implementation of Tsunami imaging software on our Linux cluster. 3D prestack depth migration feasibility studies can be undertaken here on selected sub-volumes in order to ascertain the effectiveness of the method on the dataset in question. Gocad velocity and reservoir modelling suite allows accurate layered and structural depth models intelligently combining seismic and well information



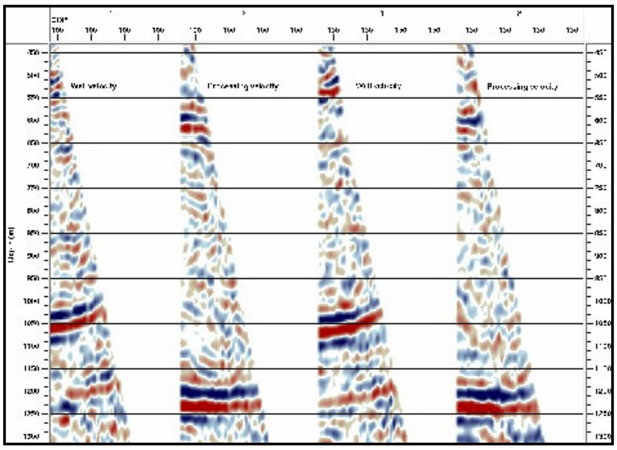


Velocity Model Building

Velocity model building (Gocad) is the most important factor governing the success of imaging projects. All available geological information has to be included in the starting model which is then interactively improved until the CRP image gathers are flat. Velocity updating involves picking the residual moveout (right), calculating the ray paths for each picked horizon through the velocity model then performing a tomographic inversion that modifies the velocity field in order to eliminate the residual moveout along the ray paths.



Although prestack depth migration accounts for raybending it doesn't account for anisotropy. In time processing flat events are required for a good stack response, multiple suppression and AVO. In depth processing we either get a result with good imaging at the wrong depth (gathers 2 & 4 right) or a result with poor imaging at the right depths (gathers 1 & 3). The solution is either to depth migrate using anisotropic parameters in Tsunami or to apply a process called depthing - here the good image is transformed back in to the time domain and subsequently back to the depth using the velocity field corresponding to the true depths.



DMT Petrologic GmbH

Karl-Wiechert-Allee 76
30625 Hannover, Germany

Phone +49-511-5413917

Fax +49-511-5414313
info-petrologic@dmt.de
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2D & 3D CRS-Stack

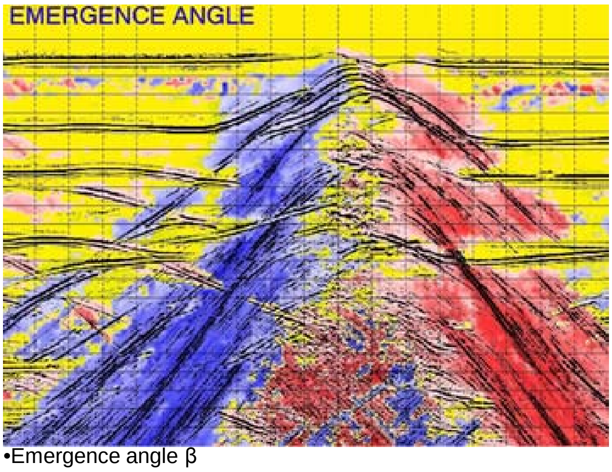
Common Reflection Surface Stack

Common Reflection Surface Stack (CRS-Stack) is a new method of zero-offset time imaging. CRS-Stack accurately approximates the zero-offset section for complex structures, even in areas with poor signal quality.

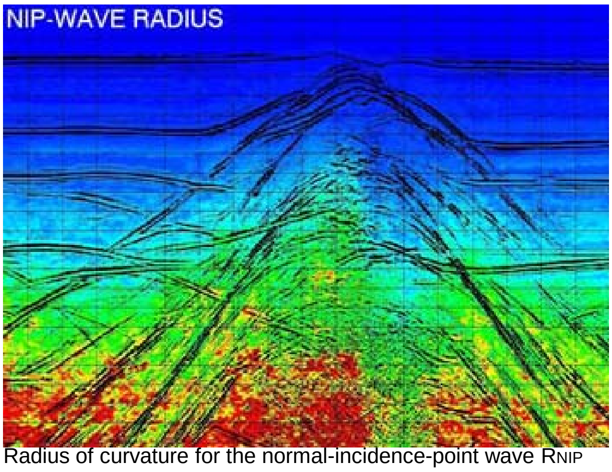
CRS stacking followed by poststack migration can produce images that are easier to interpret than prestack time or depth migrations.

CRS uses semblance techniques to characterize prestack reflection events with first- and second-order approximations.

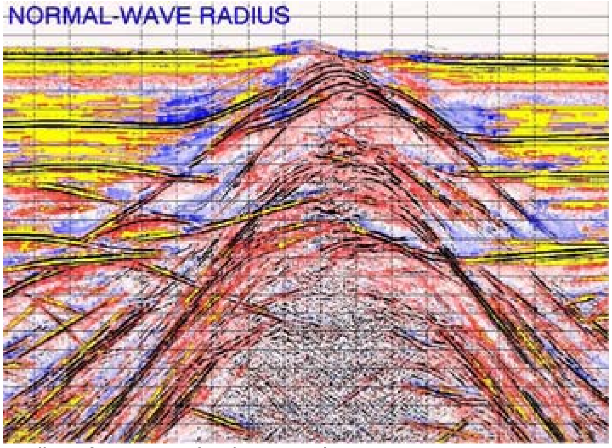
Unlike conventional stacking, events are tracked in both the midpoint and offset dimensions.



•Emergence angle β

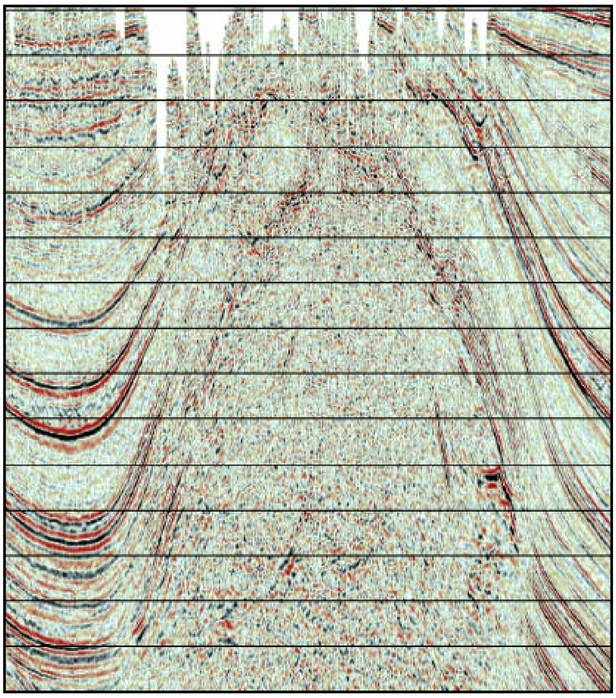


Radius of curvature for the normal-incidence-point wave R_{NIP}

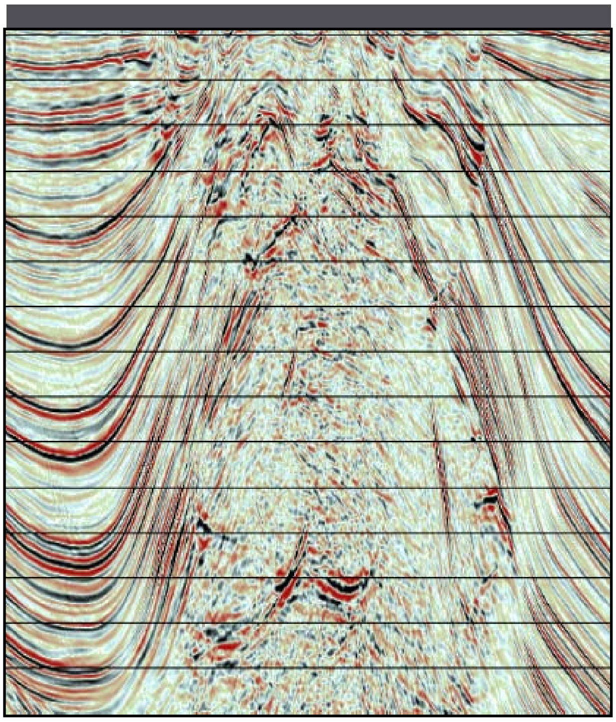


Radius of curvature for the normal wave R_N

CRS

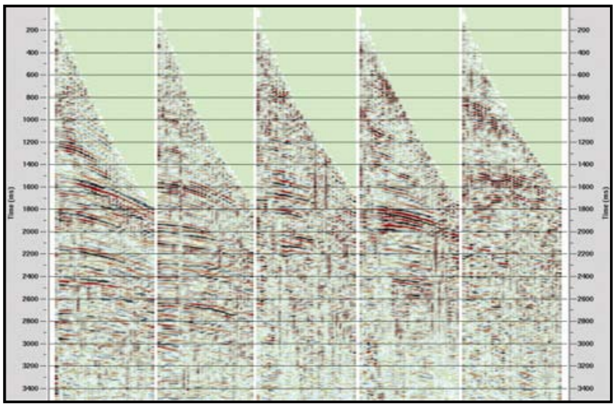


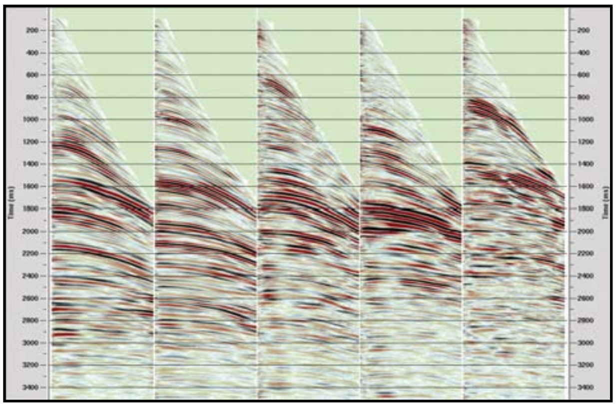
Migration of Conventional Stack

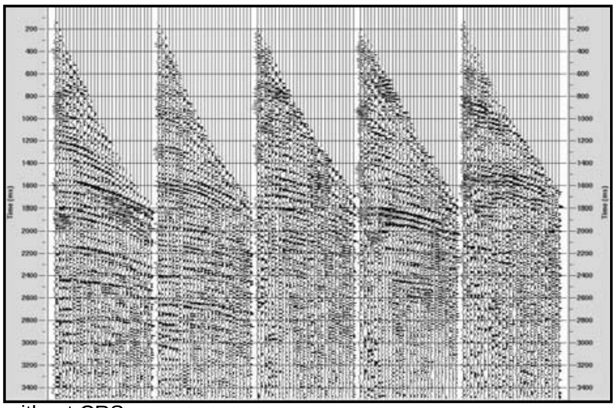


Migration of CRS Stack

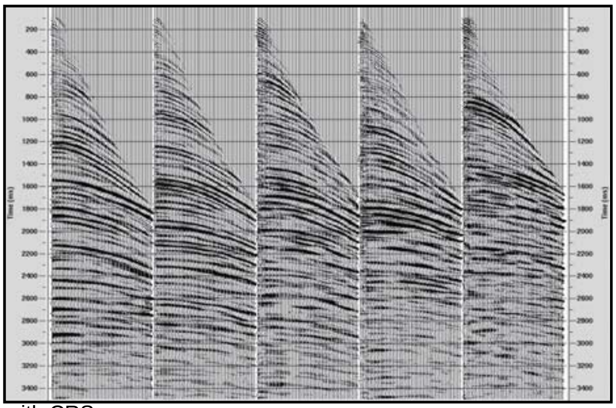
CRS Application in prestack mode: Generation of supergathers







without CRS



with CRS

DMT Petrologic GmbH

Karl-Wiechert-Allee 76
30625 Hannover, Germany

Phone +49-511-5413917
Fax +49-511-5414313
info-petrologic@dmt.de
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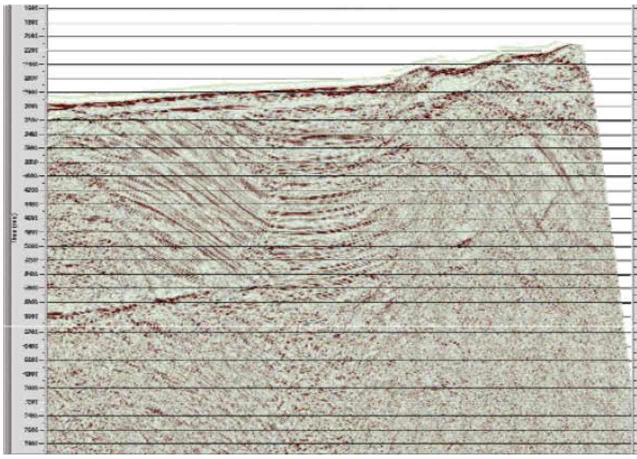
SRME

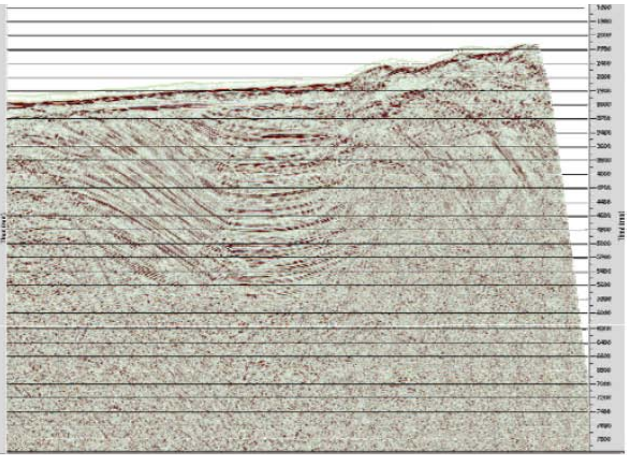
Surface-Related Multiple Elimination

SRME is a data-driven method for removing surface-related multiples. Like IMR it was developed by the Delphi research consortium at Delft University of Technology in the Netherlands.

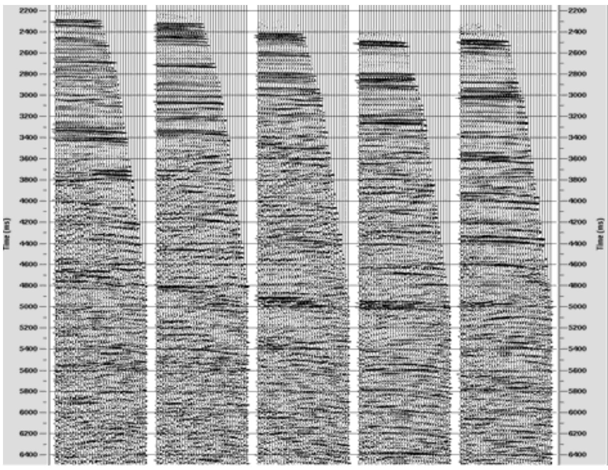
SRME requires no a priori information about the subsurface geology and can take into account the full, multi-dimensional complexity of the earth. Finally, because no a priori information is used, the required user interaction is minimized.



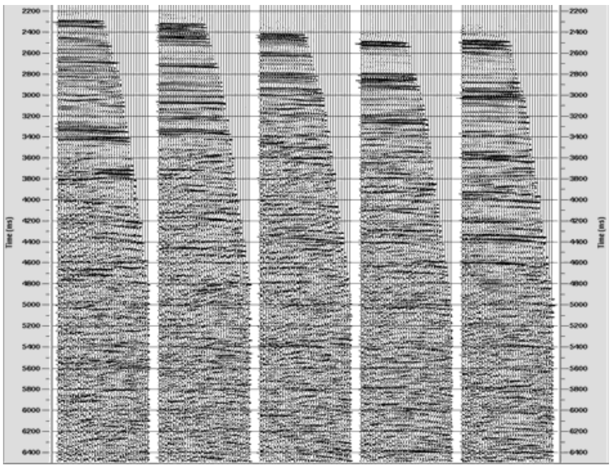
Stack without SRME



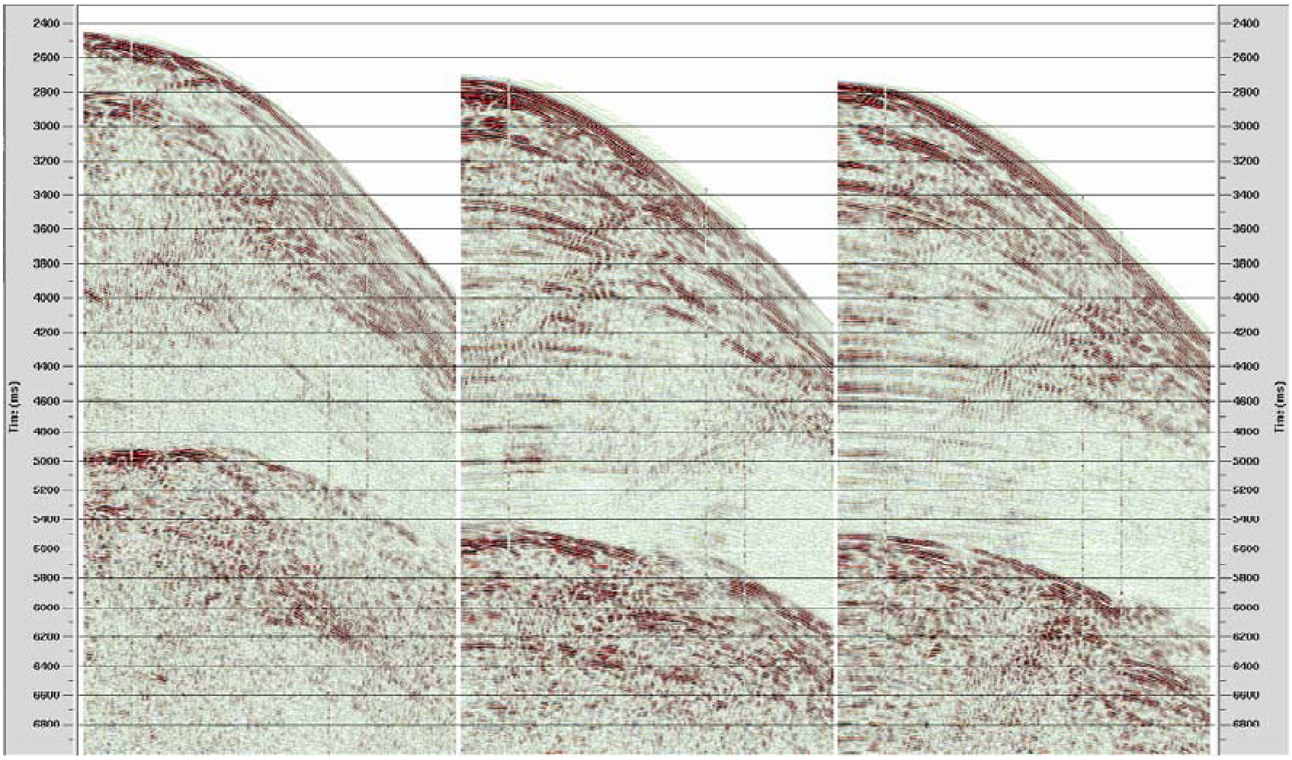
Stack without SRME



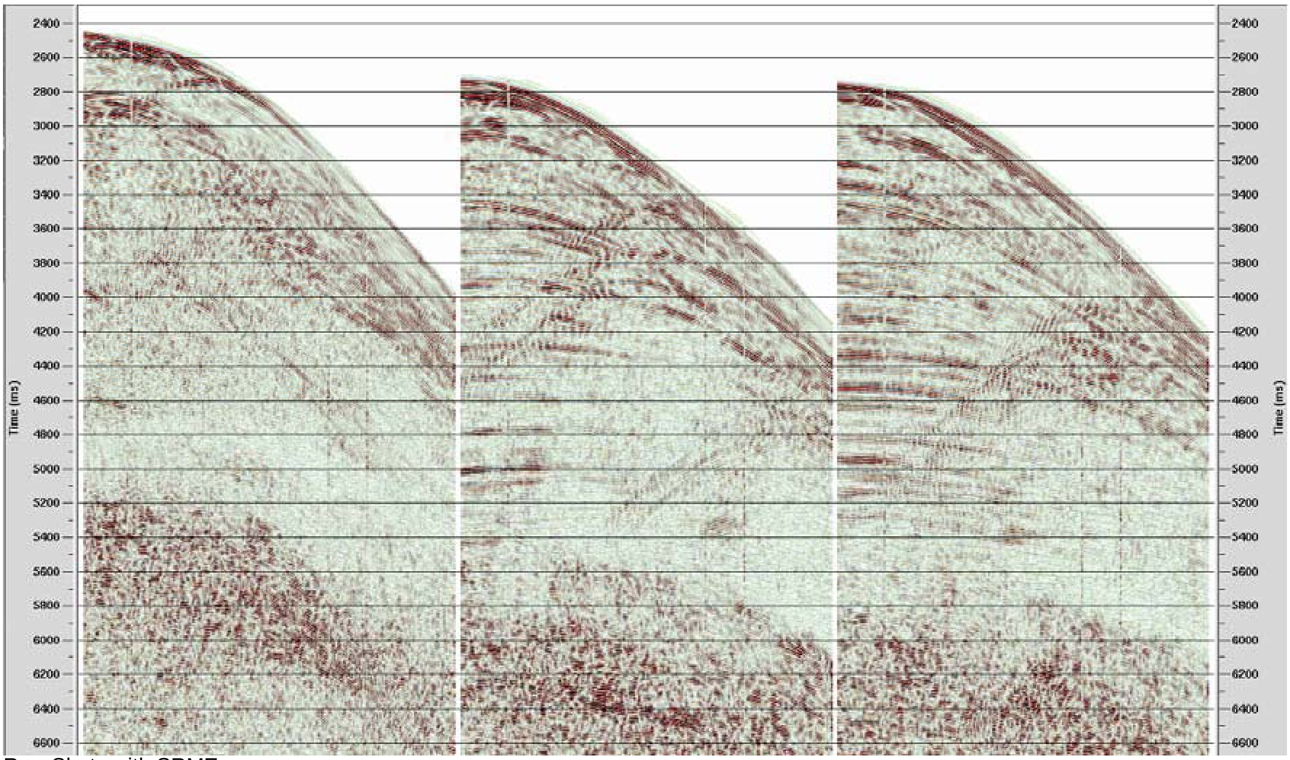
PSTM gathers without SRME



PSTM gathers with SRME



Raw Shots without SRME



Raw Shots with SRME

DMT Petrologic GmbH

Karl-Wiechert-Allee 76
30625 Hannover, Germany

Phone +49-511-5413917
Fax +49-511-5414313
info-petrologic@dmt.de
www.petrologic.dmt.de

Member of DMT Group

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IME

Internal Multiple Removal

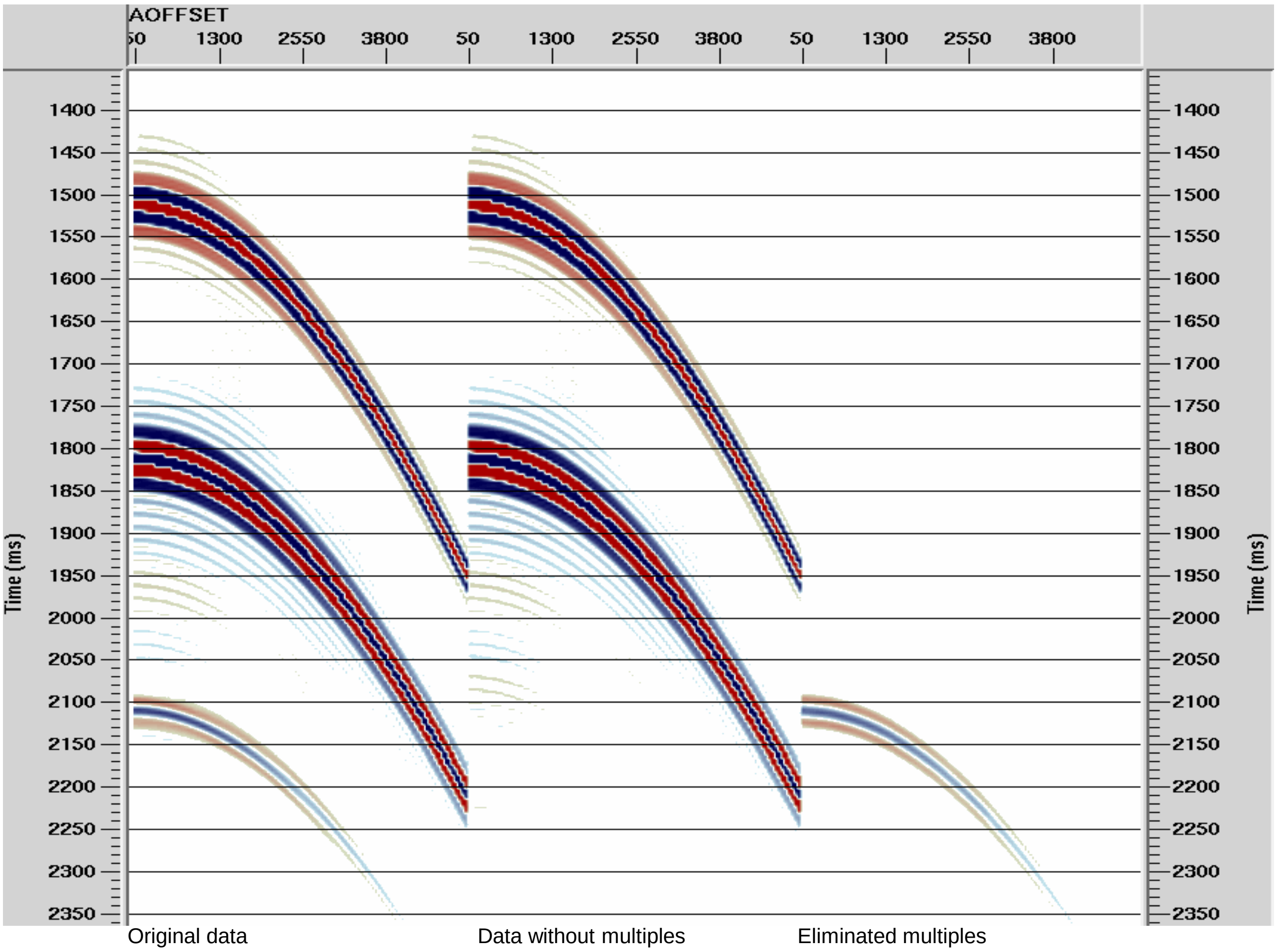
Internal Multiple Elimination(IME) is a data-driven method of multiple elimination. Like SRME it was developed by the Delphi research consortium.

In geological structures a layer with high velocities often causes internal multiples that interfere with the target areas underneath. These internal multiples can be eliminated by using IME.

Unlike other multiple elimination methods, IME is not based on velocity discrimination.
The key to a good result is careful pre-processing before applying IME.

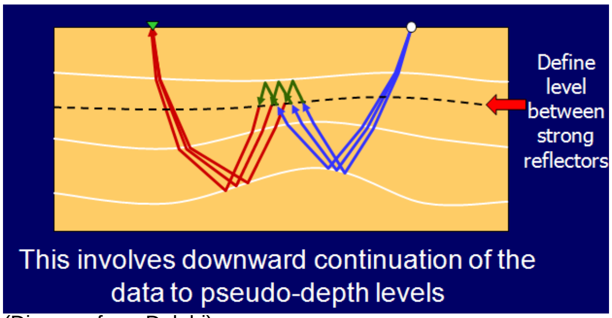
IME works especially well in combination with CRS for the prediction of multiples because CRS can considerably improve signal to noise ratio and fill acquisition gaps.

This example shows how IME cleanly eliminates internal multiples:



IME

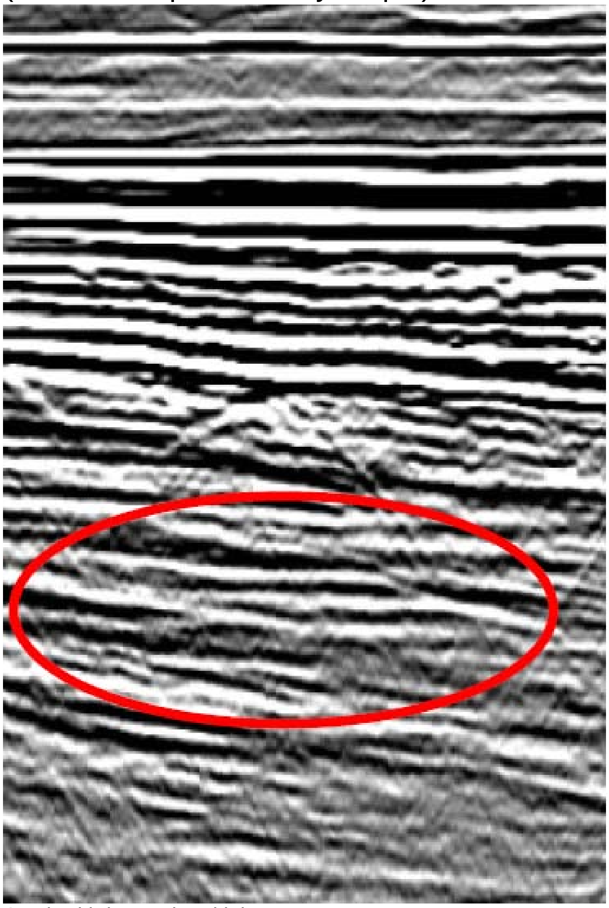
In the IME method, internal multiples are predicted in a data-driven manner. By choosing strategic time levels, multiples passing that level more than twice are predicted. The only required user-interaction is the identification of these time levels on a stack.

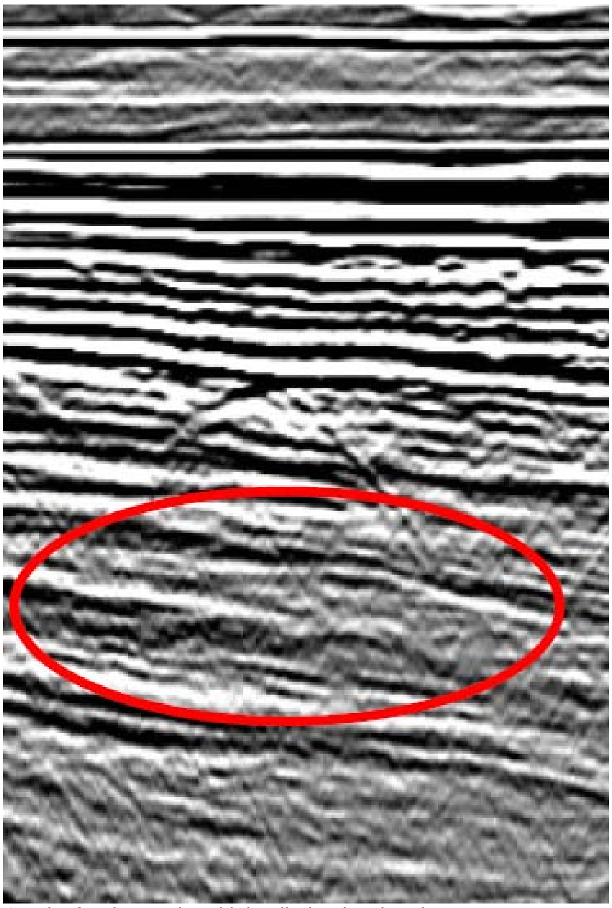


(Diagram from Delphi)

The example below shows the application of pre-stack IME applied to marine data. Note that the internal multiples in the center appear as a horizontal striping. After IME the dipping target structure is revealed.

(Results are produced by Delphi)


Stack with internal multiples


Stack after internal multiple elimination (IME)

DMT Petrologic GmbH

Karl-Wiechert-Allee 76
30625 Hannover, Germany

Phone +49-511-5413917
Fax +49-511-5414313
info-petrologic@dmt.de
www.petrologic.dmt.de

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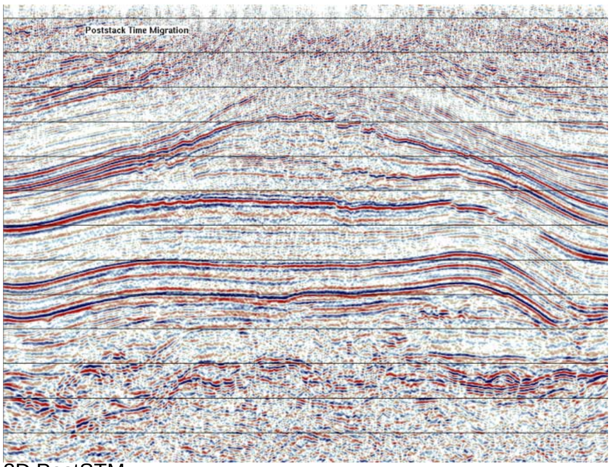
Prestack Kirchhoff 3D Time Migration

3D Prestack Kirchhoff Time Migration offers solutions to problems arising from complex geology with conflicting dips and with different stacking velocities. 3D imaging of such structures at prestack stage is the only way to resolve e.g. tilted fault blocks.

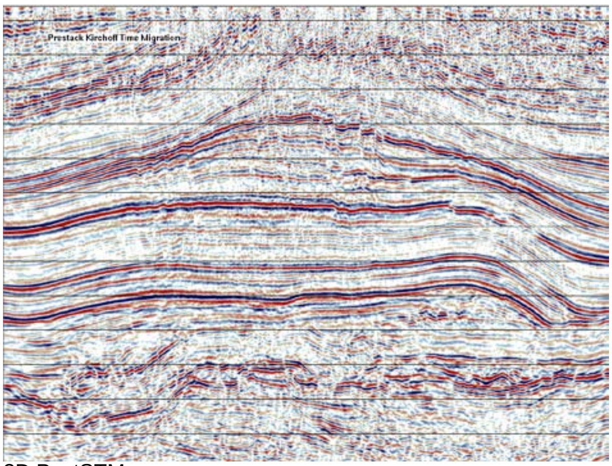
In addition the 3D PSTM generates common-reflection-point (CRP) gathers which can be used for amplitude variation with offset analysis or elastic inversion.

Further benefits are:

- Acquisition footprint compensation
- The estimated 3D RMS-velocities can be used to compute 3D interval velocities via Dix conversion
- Implementation for superior performance on our 64-node Linux cluster

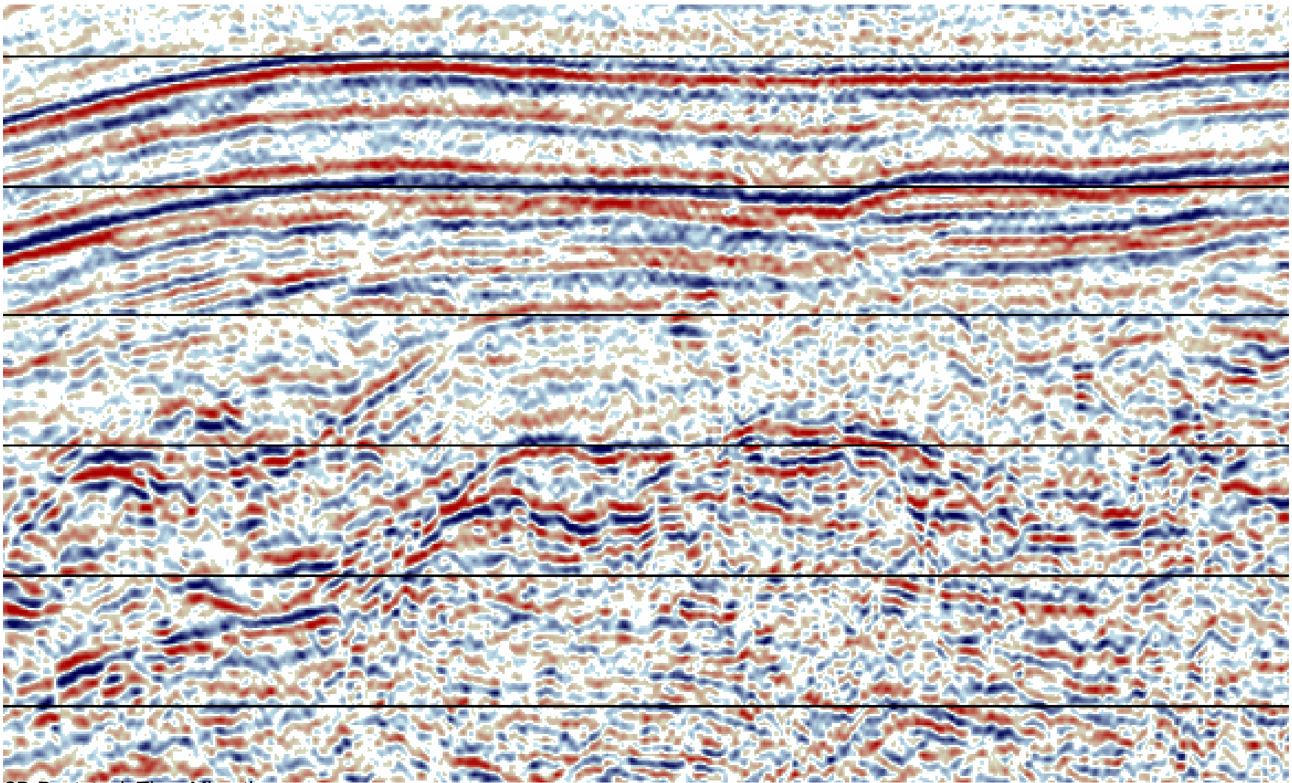


3D PostSTM

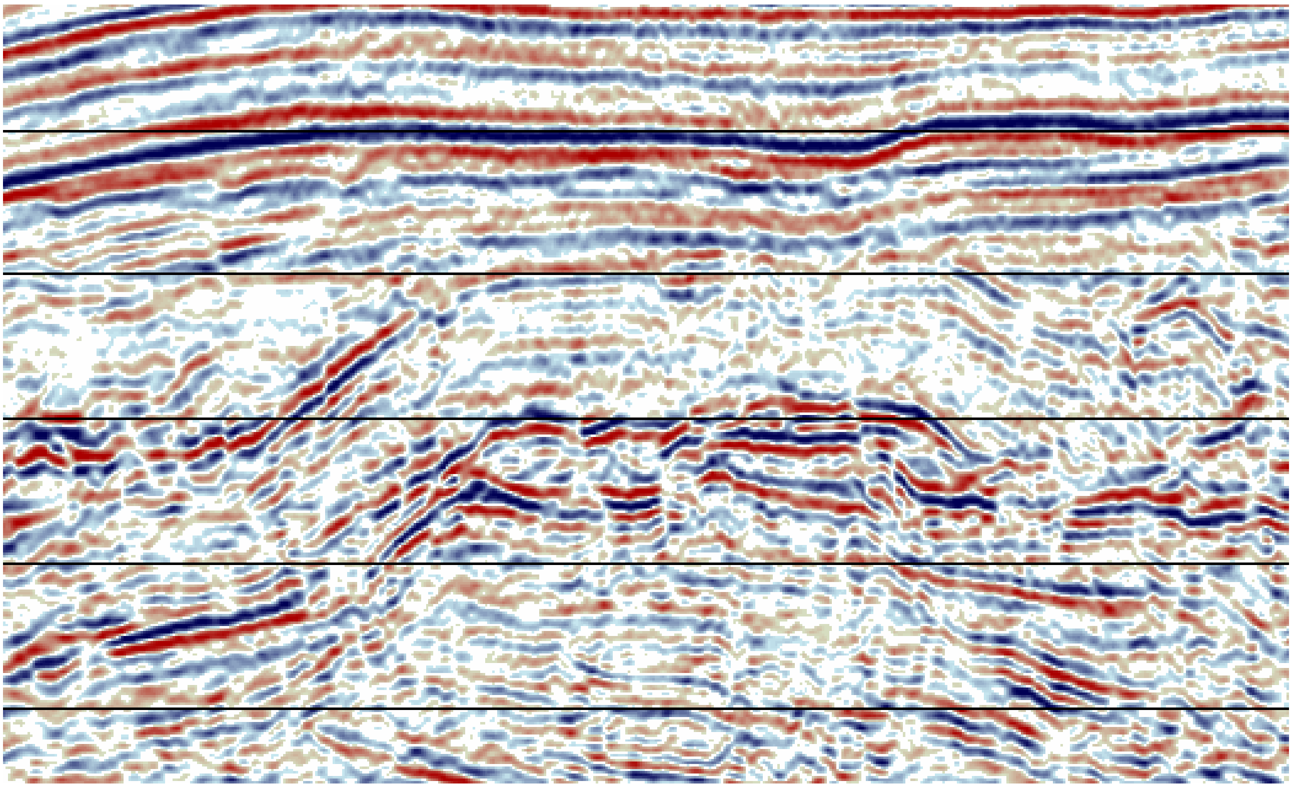


3D PostSTM

3D PSTM in actual practice



3D Poststack Time Migration



3D Prestack Kirchhoff Time Migration

DMT Petrologic GmbH

Karl-Wiechert-Allee 76
30625 Hannover, Germany

Phone +49-511-5413917
Fax +49-511-5414313
info-petrologic@dmt.de
www.petrologic.dmt.de

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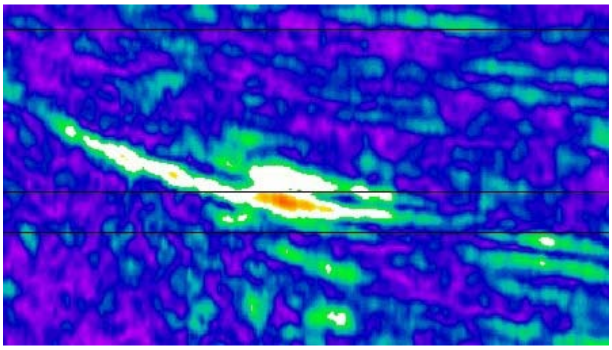
AVO

Amplitude vs. Offset

Amplitude-versus-Offset (AVO) methods analyze the reflection behavior with increasing incident angle or offset at layer boundaries. The partitioning of energy depends on the Pand S-wave velocities which vary according to the amount of hydrocarbons present. The data preparation for AVO analysis is extremely important. The presence of noise, whether coherent or random, has a negative effect on AVO analysis. Amplitude scaling processes such as AGC may in fact reduce the noise, but they destroy the real amplitude relationships of the data and are thus not acceptable. Surface consistent processing together with residual amplitude decay and residual nmo analysis contribute towards a robuster AVO result.

The AVO results can be complemented here in Hannover by the calculation of AVO response curves, AVO modeling (Hampson & Russell). Furthermore we offer here acoustic and elastic inversion as well as the seismic attributes computation through our cooperation with Rock Solid Images.

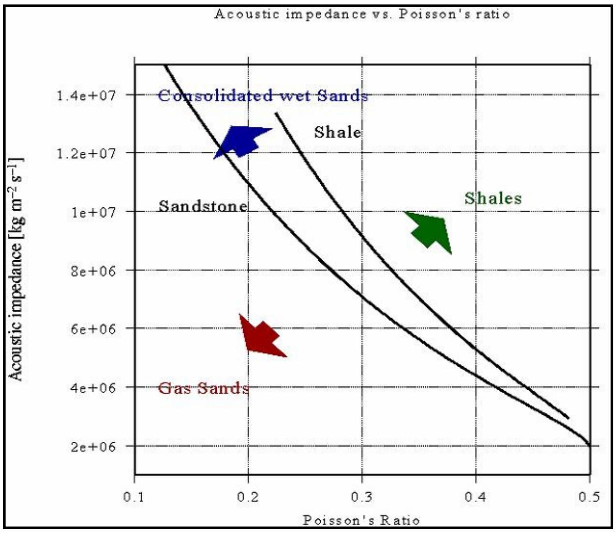


The amplitude envelope of a farnear (angle or offset) section provides a quick indication of AVO effects in the data.

Amplitude vs. Offset

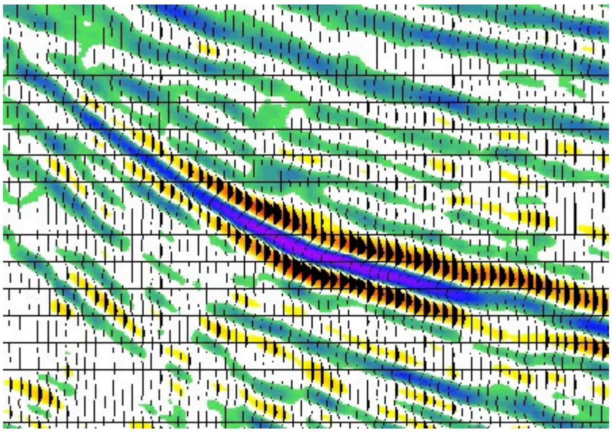
AVO crossplots are particularly useful for analyzing trends. Changes in the composition of porous rocks (eg. gas or oil replacing brine) produce a deviation from the background trend. AVO methods attempt to find and classify these anomalies and provide a statement about their validity as a prospect. Several useful crossplots provide clues as to the presence of hydrocarbons:

- AVO intercept vs gradient
- P-wave vs S-wave impedance
- P-wave impedance vs (Vs/Vp)
- Lambda*rho vs Mu*rho
- Acoustic impedance vs poisson's ratio



Smith & Gidlow (1987) using an amplitude weighted summing method of the reflection amplitudes to

determine the P- and Sreflectivity. Their fluid factor is another way of indicating the presence of hydrocarbons. Deviations from the "mudrock-line", which basically represents the regional Vp/Vs trend, may be caused by the presence of hydrocarbons.



This is a powerful indicator for reconnaissance AVO investigations in areas with limited well control. Goodway (1997) extended this and showed that it is then possible to compute elastic parameters such as Lambda (incompressibility)and Mu (rigidity) . The Lambda reflectivity (right) is a pore fluid indicator which can clarify the identification of reservoirs by separating pore fluid effects from lithology effects.

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DMT Petrologic GmbH

Karl-Wiechert-Allee 76
30625 Hannover, Germany

Phone +49-511-5413917

Fax +49-511-5414313
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www.petrologic.dmt.de

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Converted Waves

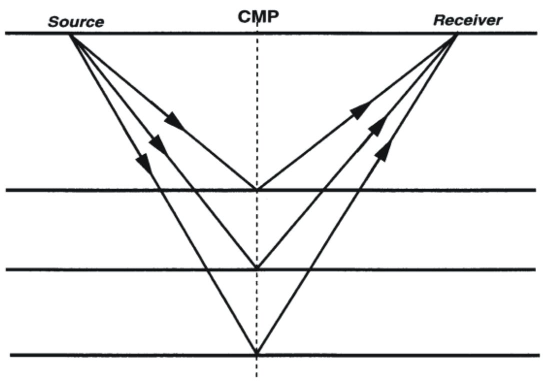
Analyses of multicomponent data provides information about anisotropy and type of
pore fluids. We have indirectly been estimating the shear properties from rocks for some
time using AVO and elastic inversion methods. With multicomponent methods, however,
we can not only directly estimate these properties, at the same time we get a better
image than we get from P-wave processing. And all this at marginally extra cost!

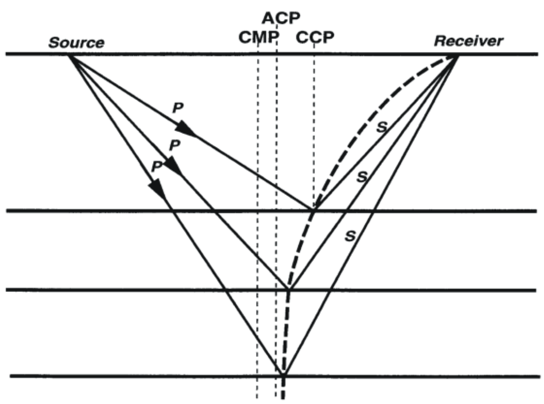
Processing considerations:- Rotation & positioning analysis

- CCP binning
- Statics solutions
- Velocity analysis (higher moveout corrections)
- Vp/Vs analysis
- Converted wave DMO and imaging.

Facts:

- P-waves travel faster than S-waves S-waves cannot exist in fluid, P-waves do
- S-waves are not greatly affected by pore fluids in rocks, P-waves are
- S-waves can be created by conversion of P-waves at rock property boundaries
- A P-wave source with 3-component geophones provides much more information
- about a reservoir than either P- or S-waves alone.





Converted Waves

Imaging applications:

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- Through gas clouds, chimneys
- Higher S-wave than P-wave impedance changes

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- Beneath salt or basalt Imaging applications:

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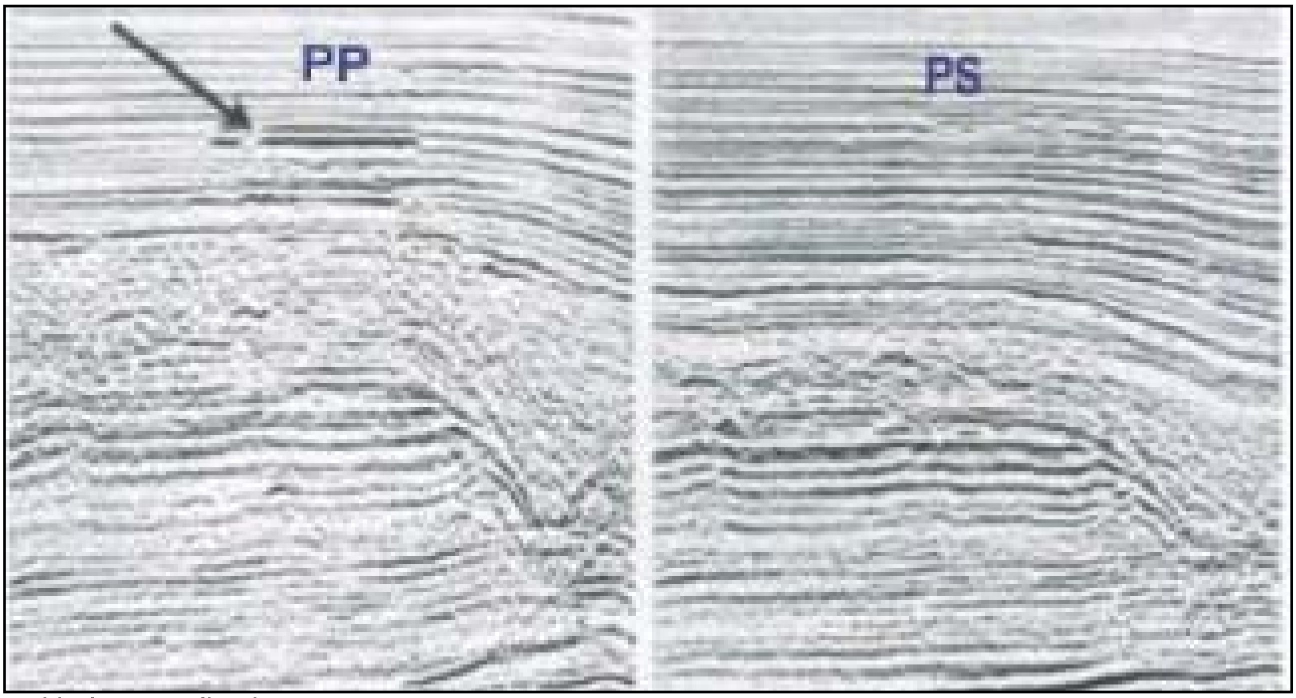
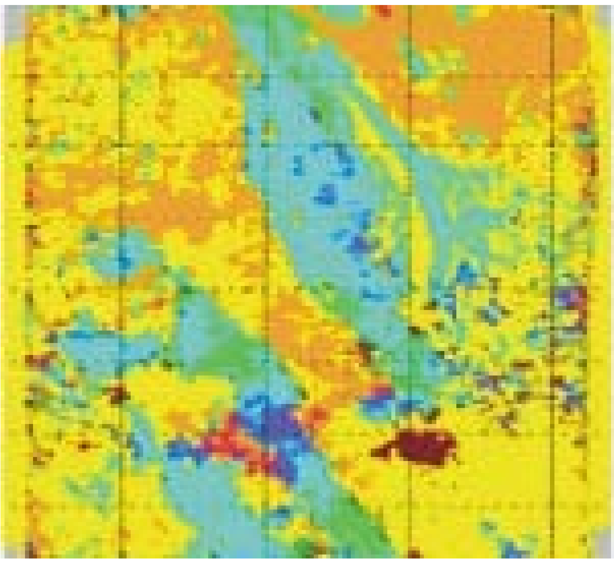
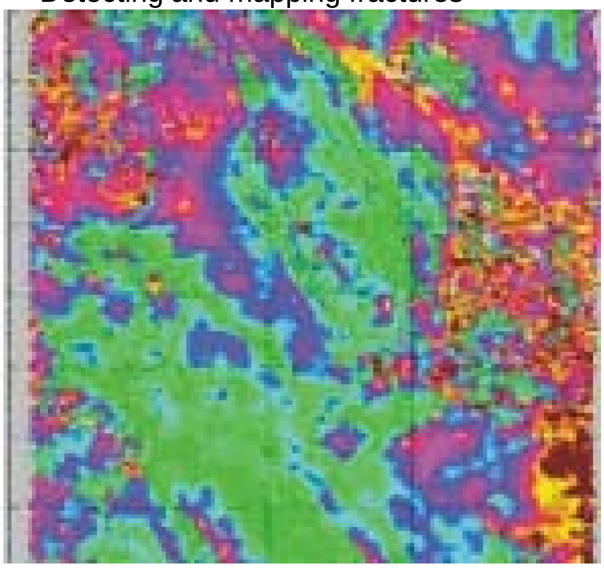


Lithology applications:

- Fluid identification – bright spot validation
- Lithology discrimination / Poisson's ratio
- Mapping hydrocarbon saturation
- S-wave splitting – anisotropy
- Detecting and mapping fractures





DMT Petrologic GmbH

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30625 Hannover, Germany

Phone +49-511-5413917

Fax +49-511-5414313
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Post-Stack Inversion

Post-stack inversion transforms a single seismic data volume into acoustic impedance through integration of the seismic data, well data and a basic stratigraphic interpretation. The resulting impedance volume can be used to predict reservoir properties away from well control.

Seismic inversion offers several benefits:.

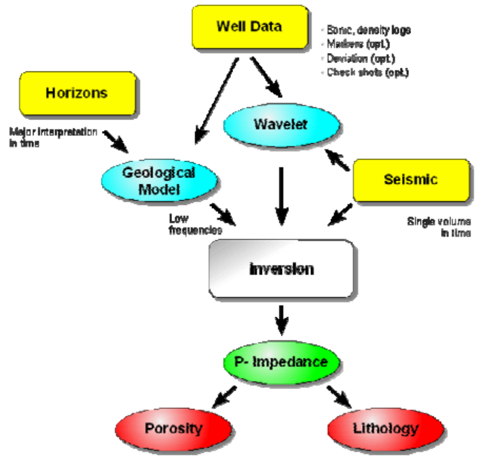
- Acoustic impedance is a layer property, whereas seismic data is an interface property. Typically stratigraphic interpretation is easier on impedance data.
- Reduction of wavelet effects, tuning and side lobes. Hence enhanced resolution of the sub-surface layers.
- Acoustic impedance is a physical rock property. It can be directly compared to well log measurements and allows a physically motivated link to reservoir properties.
- Often acoustic impedance can be related to porosity. The application of an impedance-porosity relation, derived from well log data, to the inverted impedance volume allows the mapping of the porosity distribution within the reservoir.
- Acoustic impedance can often be utilized as a reservoir discriminator to localize individual reservoir compartments.

The data input to a post-stack inversion project typically consists of a set of wells, containing sonic and density logs, optional check shots, formation markers and deviation surveys, a series of interpreted horizons, and a seismic data volume .

Generate acoustic impedance volumes from 2D or 3D seismic

Relate acoustic impedance volumes to reservoir properties such as porosity

Use sparse-spike or model-based inversion



The inversion is performed with CGG Veritas Hampson-Russell software modules GeoView, eLog, and STRATA.

Tuning removal

Constructive or destructive interference of waves from closely spaced events can lead to amplitude

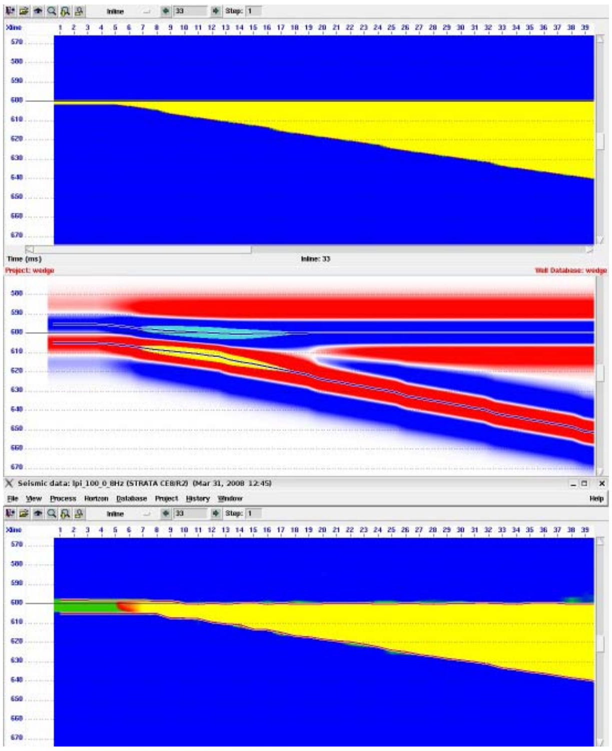
changes unrelated to any property variations within reservoir layers. An interpretation of bright spots may highlight no hydrocarbons, dimmed areas might miss profitable reservoir areas.

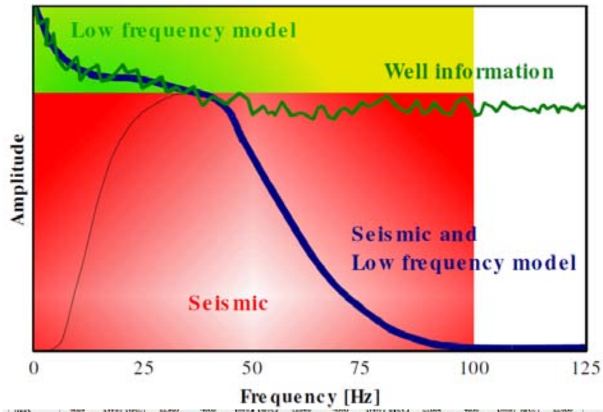
Typically seismic inversion reduces the tuning effect: for a pinching out low impedance reservoir within a uniform background, the seismic amplitudes change as the layer thickness decreases below the seismic tuning thickness. The inverted impedance however remains unchanged beyond such tuning point.

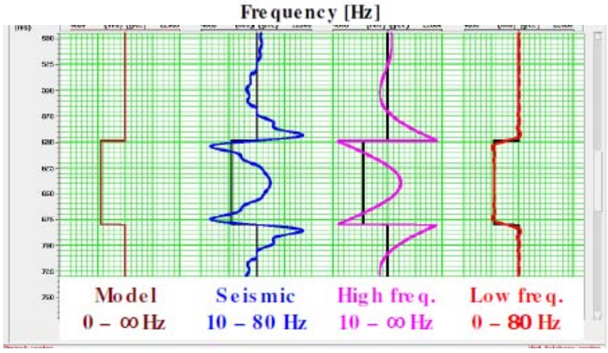
The inverted impedance may not completely resolve the thinning layer, but the corresponding layer thickness is considerably smaller than the tuning thickness. Typically inversion resolves thin beds down to half the seismic tuning thickness.

Quantitative interpretation

Traditional structural interpretation of seismic reflectors has been essentially qualitative. Both, the fine scale detail and the absolute properties are missing. During seismic inversion the missing information in the seismic is filled with low frequent information taken from a geological model derived from well data (with virtually infinite frequency content) and basic structural interpretation. For a simple low impedance reservoir model within a uniform background the information content within different frequency ranges reveals primarily three effects: within seismic bandwidth the data is centered around zero, high frequent ripples appear along the whole data and strong side lobes replace the sharp outline of the reservoir layer. Restoration of the high frequencies does not cure the side lobes and zero line trend. It only removes the high frequent ripples. In contrast restoration of the low frequencies leaves the ripples, but approaches the model very closely, enabling quantitative interpretation.







Data integration

Seismic inversion integrates data from various disciplines and domains (well data in depth, seismic interpretation and amplitudes usually in time). Typically the result is a more complete set of information than any of the individual processes can achieve alone (well correlation, geological model building, seismic AVO analysis). The successful completion of a seismic inversion study with the inherent QC's ensures rigorous consistency of all input data.

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DMT Petrologic GmbH

Karl-Wiechert-Allee 76
30625 Hannover, Germany

Phone +49-511-5413917
Fax +49-511-5414313
info-petrologic@dmt.de
www.petrologic.dmt.de

Member of DMT Group

Pre-Stack Inversion

Pre-stack inversion transforms seismic angle or offset data into Pimpedance, S-impedance and density volumes through integration of the seismic angle/offset gathers, well data and a basic stratigraphic interpretation. Other combinations of elastic parameters such as P-impedance, Vp/Vs ratio and density are equally possible. Typically two components (e.g. P-impedance and Vp/Vs ratio) are reliable, depending on target and acquisition, and can be used to predict reservoir properties away from well control.

Simultaneous seismic inversion offers several benefits:

- The output components are layer properties, whereas seismic data is an interface property.
- Reduction of wavelet effects, tuning and side lobes. Hence enhanced resolution of the sub-surface layers.

Generate P-impedance and Vp/Vs ratio volumes from 3D seismic

Relate elastic parameters from seismic to reservoir properties such as lithology, porosity, fluid fill

Enhance the reservoir property discrimination of P-impedance by an additional dimension

Avoid cross offset or angle smearing during stacking

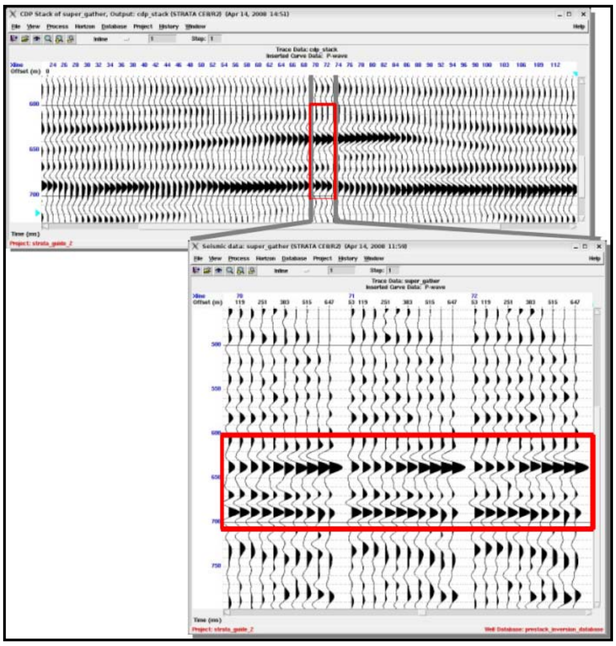
- The output components are physical rock properties. They can be directly compared to well log measurements and allow a physically motivated link to reservoir properties.
- Compared with post-stack inversion an additional dimension is available for lithology and fluid fill discrimination.
- As amplitude variations for different angles/offsets are modeled during the inversion and not averaged in the stacking process, usually the P-impedance inversion is improved.

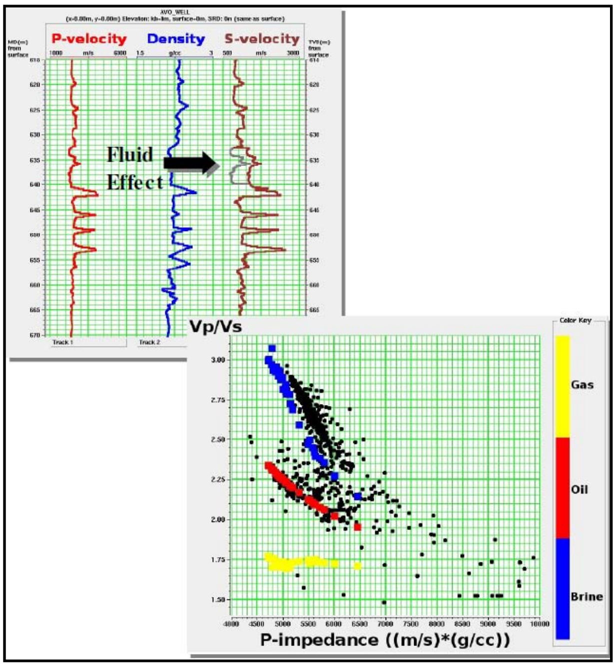
The data input to a pre-stack inversion project typically consists of a set of wells, containing sonic, shear and density logs, optional check shots, formation markers and deviation surveys, a series of interpreted horizons, and seismic offset or angle gathers.

The inversion is performed with CGG Veritas Hampson-Russell software modules GeoView, eLog, AVO and STRATA.

Avoid stacking smearing

Although stacking generally improves the signal to noise ratio, the stacked section does not necessarily represent the real normal incidence reflectivity. For data with AVO effects this can cause problems during well-tie and wavelet estimation. And where reflectivity variations are averaged out, the inverted P-impedance diverges from the true P-impedance.



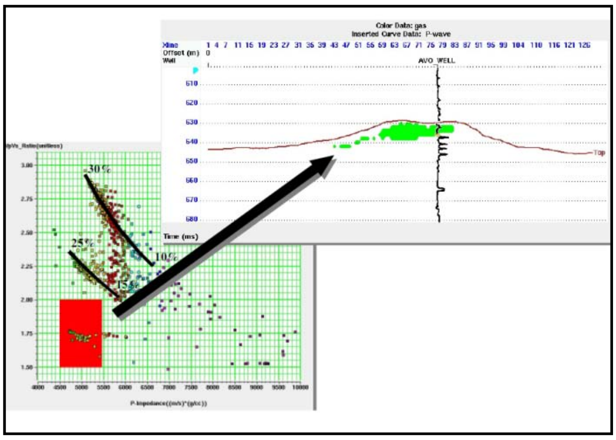


Fluid substitution

Different fluid fill might cause different seismic responses. Through fluid replacement modeling the impact of fluid changes on the elastic properties can be analyzed. Combined with synthetic seismic generation fluid replacement modeling allows the evaluation of AVO effects. Furthermore it is an important step in the log synthesis for missing or poor well log measurements.

Analysis

The combination of sedimentologic and diagenetic models with fluid replacement models can provide rock physics templates to predict lithology and hydrocarbon. Gas sands, for example, might show similar P-impedance properties as wet sands and the other lithologies in a particular region. However they might be discriminated through their lower Vp/Vs ratio.



DMT Petrologic GmbH

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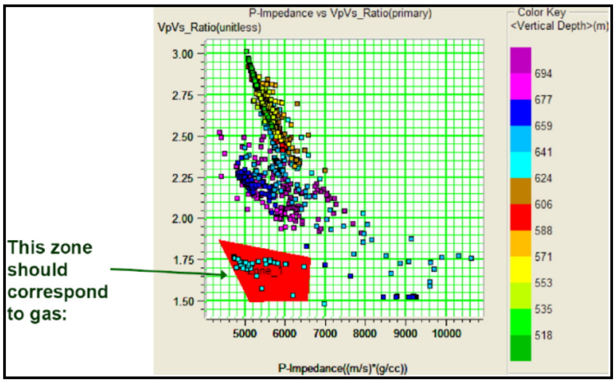
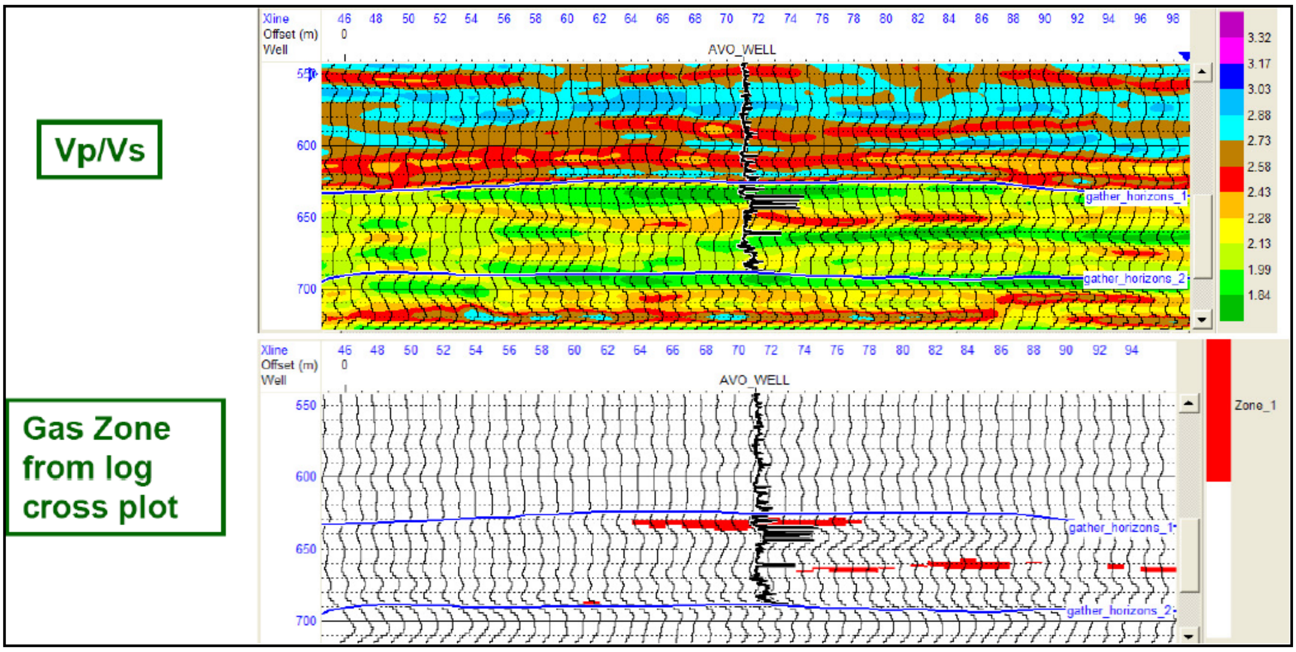
Member of DMT Group

Reservoir Characterization

Traditionally seismic data is used to develop geological models of structure and stratigraphy. However, the main goal in seismic surveying for petroleum is to find the lithology type and the presence of fluids. Therefore seismic amplitude information is used to infer rock and fluid properties. Well data has to be carefully and closely integrated with the seismic to calibrate the results. Additionally structural interpretation results and common geological knowledge are essential. Thus the success of reservoir characterization depends on the elaborate integration of various disciplines.



A successful seismic based reservoir property evaluation includes usually three steps: derivation of relevant rock properties from the seismic (for example through seismic inversion), rock physics transformation to relate the seismic derived parameters to reservoir parameters, and mapping of these parameters in 3D.



Eventually the results of a reservoir characterization study are usually used directly to build/update the static model for reservoir simulation.

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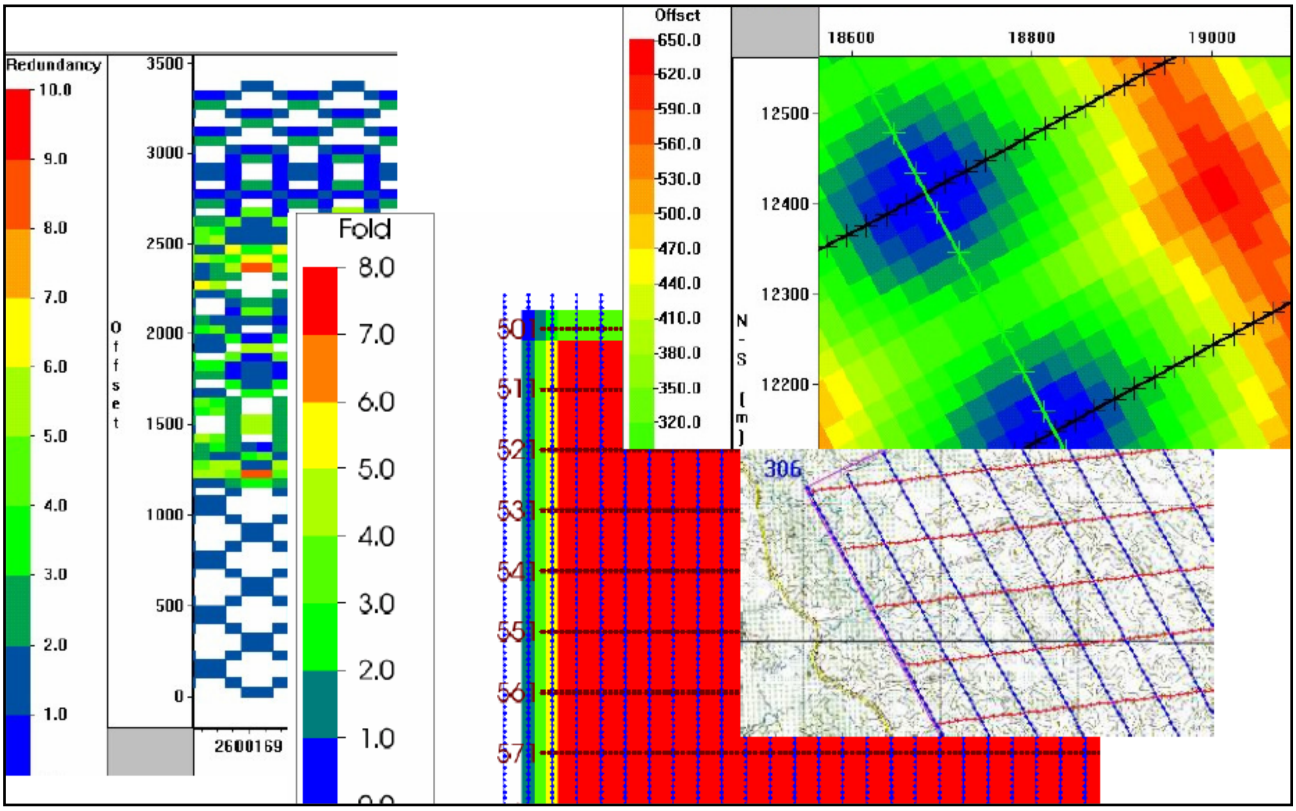
Acquisition QC & Consulting

An optimum processing result requires excellent raw data and highly professional processing skills. Petrologic Geophysical Services GmbH strives right from the start to achieve highest seismic data quality. Our team of geophysicists with considerable field experience offer the following services:

Custom-made Survey Design

We check your basic survey parameters like target depth, dips, area size, required resolution, calculate fold and offset distribution and develop a custom made Survey Design. Developed especially for urban areas or rough terrain, software like Green Mountains MESA creates a survey that fits your needs and budget.



Scouting

Our support is not just office-based - long before a survey starts we go out in the field and scoutthe area. Potential difficulties are recognized before they become problems. We look for legal, agricultural, environmental and climatic reasons to figure out the best time of the year to perform the survey. We determine the optimum source and recording parameters and equipment and assist you in formulating precise tender documents for your acquisition contractors.

Seismic data acquisition today has reached a high standard. Accurate field parameters and geometry, especially for 3D surveys, are essential for successful data processing and for interpretation.

DMT Petrologic GmbH therefore offers new field based services -bird
dogging and seismic on line quality control

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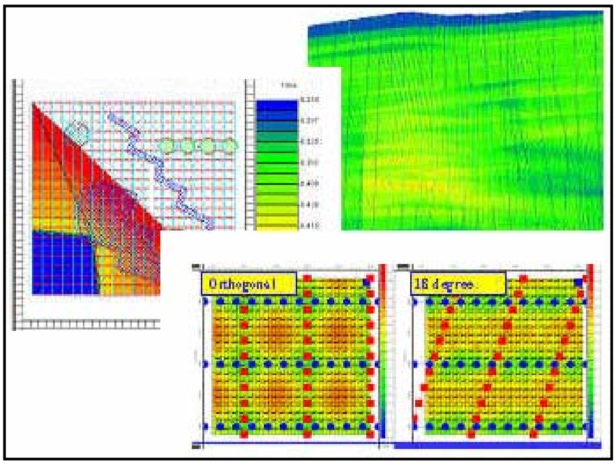
- Bird dog
  Working as clients representative
  General equipment checks
  Daily quality checks
  Daily, weekly and monthly reporting



- QC
  Geometry planning
  Online seismic data control
  Geometry check
  SPS files

Petrologic uses commercial and in-house developed software.

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DIN EN ISO 9001 zertifiziert

Hardware

Petrologic has processing centres in Germany and Libya.

Our main processing centre in Hanover, Germany is equipped as follows:

- Linux Cluster (96 nodes @ 2.6 GHz 64-bit)
- Linux Cluster (72 nodes @ 2.4 GHz 32-bit)
- 140 Terrabyte disk capacity (incl. 7x RAID5 and 2x RAID6 storage systems)
- 73 UNIX/LINUX /PC processors 32-bit/64-bit
- 6Mbit LWL internet connection for remote access
- LTO4, LTO3, DLT, Exabyte, 4mm, 9 track
- IBM 3480/3490 /3590/ 3592 tape drives
- Plotter

Our equipment combined with different fast-operating software solutions allows us to work projects time- and cost-effectively.

With the introduction of a supplementary 64-bit Linux cluster in November 2007, we increased performance on large-scale 3D and imaging projects.

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